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Wading Bird Depredations on Channel Catfish *Ictalurus punctatus* in Northwest Mississippi

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Abstract.—We interviewed farm managers about their perceptions of wading bird problems and conducted preliminary surveys of wading bird populations at 67 randomly selected channel catfish *Ictalurus punctatus* pond complexes in northwest Mississippi during December 1995. At a subsample of 24 complexes and 10 other complexes previously surveyed in 1990, we surveyed wading bird populations bimonthly throughout the year in 1996 and observed great blue herons *Ardea herodias* and great egrets *Ardea alba* feeding at catfish ponds. Seventy-five percent of farm managers questioned felt that wading birds were causing losses to their fish stocks, and 74% believed the problem was increasing. Consistent with interview results, 88% of the pond complexes surveyed had one or more wading birds present. Despite reported harassment programs by producers, great blue heron densities at 10 complexes previously surveyed in 1990 had increased by more than eightfold in 1996. Great blue heron densities varied with location, season and time of day, but the average 127-ha farm supported about 78 herons and 56 great egrets. Despite similar populations, the potential impact of these two species was quite different. Live catfish, averaging 10.3 cm in length (circa 10 g) comprised only 8% of the egret diet by weight, and most of the fish were obtained from fingerling ponds during periods when these fingerlings may be weakened by the bacterial disease, enteric septicemia of catfish. In contrast, live catfish, averaging 16 cm in length (circa 34 g), comprised 44% of the great blue heron diet by weight. Herons foraged from both fingerling and food fish ponds, primarily in the early morning and evening. Based on average population densities and foraging rates, herons at the average 127-ha farm in northwest Mississippi consumed 114,000 (circa 3,900 kg) catfish, annually. However, further studies are recommended to document production losses.

In the past ten years, production of channel catfish *Ictalurus punctatus* in the United States has increased 121% to 214 million kg annually (USDA 1997). Concurrently, populations of fish-eating birds have increased (Fleury and Sherry 1995), as has producer perception of economic losses associated with predation by these birds (Stickley and Andrews 1989). In 1996, approximately 70% of all catfish producers surveyed indicated that bird predation on their fish stocks was a serious problem, and this problem was most frequently cited by catfish producers in Mississippi (USDA 1998). The two bird species most often reported as problems were the double-crested cormorant *Phalacrocorax auritus* (53%) and the great blue heron *Ardea herodias* (42%). Egrets *Egretta* spp. were the third most frequently cited birds (16%).

Although the potential for economic losses is well documented for the double-crested cormorant (Stickley et al. 1992; Glahn and Brugger 1995), less is known about the magnitude of heron and egret populations and their potential impact on catfish production. Ross (1994) studied the foraging behavior of great blue herons and great egrets *Ardea alba* at catfish farms in Alabama, but did not provide information on their populations or their potential impact to catfish production. Most catfish farms in Mississippi are concentrated along the flood plain of the Mississippi River in the northwestern part of the state, an area that is commonly referred to as the Delta region of Mississippi. In this region, two previous studies (Hodges 1989; Stickley et al. 1995) that assessed the impact of herons and egrets were limited to one county (Humphreys County), and only certain sea-

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sons of the year. In the more recent study, Stickley et al. (1995) studied great blue heron populations at 19 catfish complexes during the periods of June through December of 1989 and 1990. A more comprehensive assessment of the impact of wading birds in the Delta region of Mississippi was needed and required knowledge of both herons and egrets throughout the region and over all seasons.

Materials and Methods

Sampling design

A two-stage sampling design was used to assess heron and egret populations in Bolivar, Humphreys, Leflore, Sunflower and Washington Counties in the Delta region of Mississippi. These counties were selected because they incorporated more than half the land area of the region and had almost 80% of the Delta's catfish pond acreage. From U.S. Geological Survey topographic maps where catfish pond complexes had been plotted, we randomly selected 100 complexes, confined within section lines, representing each county in proportion to the total pond acreage in that county. Where pond complex size (>150 ha) precluded accurate censusing, we randomly selected only a portion of the complex to survey. We then visited the 100 complexes to seek permission to survey wading birds and assess vehicle access to the ponds. This resulted in 67 suitable complexes, ranging in size from 4.4 to 150.7 ha ($\bar{x}$ = 48.9 ha), which were surveyed during December 1995. Based on these initial (Phase I) surveys, we divided these complexes into two groups—those having greater and those having less than the median number of wading birds of all species observed—and randomly sampled 12 complexes from each group starting in January 1996. Additionally, we randomly sampled 10 of the 19 complexes sampled by Stickley et al. (1995) for inclusion in our subsequent (Phase II) surveys.

Phase I Surveys

During initial surveys in December 1995, we interviewed each farm manager about production practices at the specific ponds surveyed, his perception of wading bird problems, methods of controlling wading bird predation and costs of control at his farm overall. To obtain an initial estimate of wading bird populations, we drove along levees and recorded all wading birds observed within the vicinity of ponds. We conducted two surveys, one during the first hour after sunrise and the second during the last hour before sunset, to sample bird abundance during peak periods of wading bird activity (Stickley et al. 1995).

Phase II Surveys

Following procedures of Stickley et al. (1995), we surveyed wading bird populations and observed the feeding behavior of herons and egrets bimonthly throughout the year at 34 complexes. We surveyed bird populations four times/d at 3- to 5-h intervals, starting at sunrise and ending at sunset. Based on minimal nocturnal activity expected (Stickley et al. 1995), we restricted nocturnal censuses using night vision equipment (King and King 1994) or high powered spot lights to six selected pond complexes that were surveyed starting 2 h after sunset. These complexes were selected based on having greater than average heron numbers occurring near dusk.

Between censuses, the feeding behavior of great blue herons and great egrets was observed at ponds where the most birds had been previously recorded. Observations were made to assess diet (Ross 1994; Stickley et al. 1995) because they provide results comparable to stomach content analysis (Stickley et al. 1995). Using a vehicle as a blind, an observer randomly chose individual birds of each species that were farthest from the vehicle, but still clearly visible. Choosing birds farthest from the vehicle reduced the effect of the observer on the bird's behavior and birds were typically more than 100 m away. Individual birds were constantly observed for 30 min through a 15–45×-spotting scope that allowed for reasonably accurate identification of fish common to catfish ponds. However, when fish were extremely small (<5 cm) we often reported these as unknown even though we could tell they weren't catfish. When the bird flew or disappeared before the end of the observation, another bird was selected for observation for the duration of the 30-min period. For each individual observed, we recorded the start and end times of the observation, the prey species consumed, its length and whether it was taken alive or dead. We judged whether the prey fish was alive by its movement in the bird's bill (Stickley et al. 1995). This was confirmed, in part, by the behavioral differences in the bird's capture technique (Forbes 1987) and the time needed to manipulate live and dead prey (Dorr et al., in press). Dead catfish were most often in a state of rigor mortis and were readily identified by their rigid body condition. If fish condition could not be assessed based on these criteria, they were assumed to be alive. Otherwise, they were presumed to be dead. We estimated prey length by comparing it to the reported mean bill length of the bird species observed. This method of estimating fish length has been shown to be accurate within 2 cm (Forbes 1987). We later converted these fish lengths to fish body mass using species-specific length-to-mass equations (Steeby et al. 1991; Kohler and Hubert 1993; Murphy and Willis 1996). Although more recent length-to-mass equations are available for catfish fingerlings (Steeby 1995), we used previously published equations (Steeby et al. 1991) in order to directly compare our results to those of Stickley et al. (1995). Where length to mass equations were unavailable, i.e., mosquitofish *Gambusia affinis,* we weighed samples of these fish in 2.54-cm size class intervals to estimate body mass at these lengths. In the case of unknown fish, we assumed they had the same length-to-mass relationship as the most prevalent wild-spawned fish consumed, i.e., green sunfish *Lepomis cyanellus.* A one-way analysis of variance (Steel and Torrie 1980) was used to examine differences in bird densities among facilities, counties, seasons and times of day. A Tukey's test (Steel and Torrie 1980) was used to separate differences among means. A *t* test (Steel and Torrie 1980) was used to examine differences in bird densities between years and in fish lengths consumed between herons and egrets.

Results

Phase I Surveys

Based on interviews and farm maps obtained, we surveyed wading birds on 3,323 ha of catfish ponds. Most ponds (87.4%) were cultured at a density of 12,000 to 25,000 catfish/ha in a three-batch cropping system. One-third of the fish by number were fingerling or stocker size fish which are the most likely prey for wading birds. Approximately 10% of the ponds were fingerling ponds, typically stocked at 250,000 fish/ha, with the remainder being brood fish ponds. In addition to catfish, most food fish ponds were reported to contain varying levels of wild-spawned fish, such as gizzard shad *Dorosoma cepedianum* and green sunfish.

Seventy-five percent of 47 managers responding believed that wading bird predation caused production losses of their fish stocks, and 74% of 46 managers considered the problem to be increasing. Although the majority (≥50%) of the managers reported the losses to occur at all ponds, year round, those specifying where and when problems occurred identified ponds with fish diseases and fingerling ponds during the period of November through April. When asked to rank the relative importance of all avian predators at their farm, most (60%) ranked great blue herons second after cormorants, while 33% ranked herons as the number one problem bird. The great egret was most often (81%) ranked third after the cormorant and great blue heron. The median loss of fingerling fish from all causes was reported at 10%. Managers considered that wading birds might be responsible for al-

TABLE 1. *Mean ± SEM densities (birds/water ha) of great blue herons (Herons) and great egrets (Egrets) occurring within an hour after sunrise and one hour before sunset at a number (N) of randomly selected catfish pond complexes in five counties in northwest Mississippi, December 1995.*

Species	Bolivar (N = 3)	Humphreys (N = 22)	Leflore (N = 13)	Sunflower (N = 21)	Washington (N = 8)	Overall (N = 67)
Herons	0.26 ± 0.15	0.16 ± 0.04	0.63 ± 0.19	0.31 ± 0.09	0.23 ± 0.10	0.31 ± 0.05
Egrets	0.07 ± 0.05	0.05 ± 0.02	0.05 ± 0.04	0.04 ± 0.04	0.01 ± 0.01	0.04 ± 0.01

most half (median = 45%) of this total loss of fingerlings. All managers reporting a wading bird problem used shooting, vehicle patrols and various scare devices to ward off these birds. The median annual cost per producer for employing these control measures was reported at $4,000.

Consistent with interview results, 88% of pond complexes surveyed once in December 1995 had one or more wading birds present. Great blue herons were distributed at 88% of the complexes, but only 32% had great egrets present. These were the only two wading bird species observed during our initial observations of 67 complexes, but small numbers of snowy egrets *Egretta thula,* little blue herons *Egretta caerulea,* black-crowned night herons *Nycticorax nycticorax* and wood storks *Mycteria americana* were infrequently observed during our more intensive observations at 34 complexes throughout the year. During initial surveys great blue heron densities averaged 0.31 birds/ha, but densities varied greatly

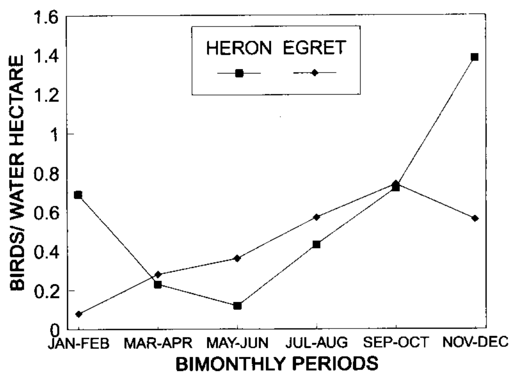

FIGURE 1. *Bimonthly changes in great blue heron (Heron) and great egret (Egret) densities at 34 catfish pond complexes in northwest Mississippi, 1996.*

among complexes (coefficient of variation = 140.3%) and ranged from 0 to 2.50 birds/ha. Great blue heron density varied by county (F = 2.82, P = 0.03). Leflore County had the highest density at 0.63 birds/ha and differed (Tukey's, P < 0.05) from Humphreys County, having the lowest density of 0.16 birds/ha (Table 1). Great egrets averaged only 0.04 birds/ha, but achieved a density up to 0.77 birds/ha. Great egret densities differed (F = 2.29, P = 0.0003) among facilities, but not (F = 0.28, P = 0.89) among counties (Table 1).

Phase II Surveys

Based on our bimonthly survey results throughout the year, great blue herons occurred at a mean density of 0.617 birds/ha (SEM = 0.0653), with great egrets occurring at a mean density of 0.439 birds/ha (SEM = 0.0813). Great blue heron densities varied seasonally (F = 8.95, P = 0.0001) with the highest density occurring from November to December (Fig. 1). The lowest densities occurred in the spring (March–April) and early summer (May–June) (Fig. 1). Great egret densities did not differ (F = 1.56, P = 0.1722) seasonally (Fig. 1). Heron density varied (F = 9.92, P = 0.0001) with time of day, with the highest density occurring near dusk. Night observations at selected facilities taken 2 h after dusk indicated a significant reduction (Tukey's P < 0.05) in heron density, with numbers averaging only 1% of those seen at dusk. Great egret densities also varied (F = 8.51, P = 0.0001) during the day, with mid-afternoon differing (Tukey's P < 0.05) from all other times except mid-morning.

TABLE 2. *Percent occurrence (% N) and percent biomass (% wt) of prey items taken by great blue herons and great egrets in northwest Mississippi, 1996.*

	Great blue heron		Great egret	
Species	% N	% wt	% N	% wt
Live catfish	27.3	44.1	4.7	8.1
Dead catfish[a]	17.9	38.5	8.4	20.2
Sunfish	18.7	8.9	31.7	48.4
Gambusia	11.8	0.4	15.2	1.8
Shad	2.5	3.3	8.5	8.5
Other/unknown[b]	21.9	4.8	31.2	13.0

[a] Presumed dead based on lack of movement in the bird's bill and behavioral differences in the bird's capture and manipulation of dead prey.

[b] Small (<5 cm) prey that was clearly not a catfish, but that could not be accurately identified.

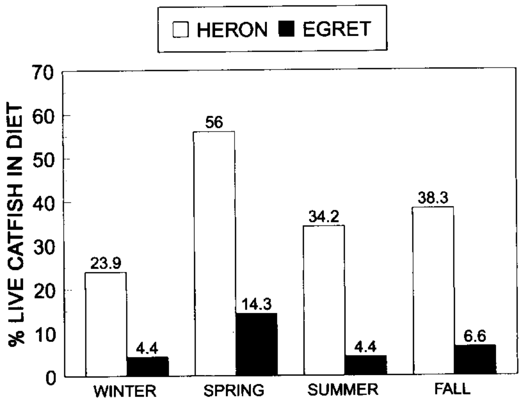

FIGURE 2. *Seasonal changes in the percent occurrence of live catfish in the diet of great blue herons (Heron) and great egrets (Egret) at 34 catfish pond complexes in northwest Mississippi, 1996.*

Very few egrets were observed at dawn or dusk and none were seen at night.

In comparison to heron densities at ten facilities surveyed from June through December in 1990 by Stickley et al. (1995), we found that heron densities during the same period in 1996 had significantly (t = 2.39, P = 0.04) increased by more than eight times, from 0.16 herons/ha to 1.33 herons/ha.

Wading Bird Diet and Foraging Rates

During 278.5 h of observations, great blue herons consumed 76 live catfish or 0.273 live catfish/h. During 94.9 h of observations, great egrets consumed 29 live catfish for a similar foraging rate of 0.306 live catfish/h. No other wading bird species was observed for a sufficient amount of time to ascertain their diets. Live catfish consumed by great blue herons averaged 16.1 cm (SEM = 0.61) in length and differed (t = −6.99, P = 0.0001) from the average 10.3-cm (SEM = 0.56) live catfish consumed by great egrets. Considering numbers of fish prey consumed by great blue herons, live catfish comprised 27% of the diet, dead catfish 18%, while live and dead wild-spawn fish made up 55% of the diet (Table 2). In contrast, the diet of great egrets consisted of 5% live catfish, 8% dead catfish and 87% live and dead wild-spawn fish (Table 2). Wild-spawn fish in both cases were predominantly sunfish (Table 2). Based on estimated fish mass calculated from observed fish lengths, the percent biomass in the diet of great blue herons was 44% live catfish, 38% dead catfish and 18% live and dead wild-spawn fish (Table 2). On a percent biomass basis, the great egret diet was 8% live catfish, 20% dead catfish and 72% live and dead wild-spawn fish (Table 2).

The percent occurrence of live catfish in the diet appeared to vary seasonally with the highest percentage occurring in both species in the spring (Fig. 2). Seasonal variation in the consumption of live catfish was most conspicuous with egrets, with two-thirds of all catfish either being consumed in the spring or fall. Despite the small percentage of fingerling ponds surveyed, 41% of live catfish observed consumed by great blue herons came from fingerling ponds, and 66% were obtained during a period near dawn or dusk. With great egrets, 70% of the live catfish consumed were from fingerling ponds.

Discussion

As reported by catfish producers, wading birds, particularly great blue herons, are abundant avian predators occurring at nearly all catfish farms. Great egrets were less widely distributed and occurred in lower densities than herons during the winter but equaled or exceeded great blue heron densities in the summer and fall. Our study suggests that great blue heron numbers at catfish farms in the Delta region of Mississippi have greatly increased over the past 5 yr. This was despite reported harassment programs conducted by catfish producers to control these birds. However, great blue heron and great egret numbers vary greatly between farms and geographic locations within this region. Although great blue herons are year-round residents at catfish farms, their numbers appear to peak in midwinter with the addition of migrant birds and are at their lowest during the breeding period in the spring. In contrast, egret numbers peaked in the summer and fall and were at their lowest in winter. Because of this seasonal variation in wading bird numbers, data from these more intensive surveys throughout the year probably better reflects the average catfish farm populations for both species. These average population estimates are based on diurnal surveys only since, as indicated by Stickley et al. (1995), nocturnal foraging by herons and egrets appears to be negligible.

Assuming the average heron density at 19 complexes in Humphreys County was representative of the more than 41,000 ha of catfish ponds in the Delta region of Mississippi, Stickley et al. (1995) estimated that the catfish industry in this region supported a population of approximately 7,000 herons in 1990. Considering our average heron density of 0.62 birds/ha surveyed at 34 complexes in five counties, the total heron population utilizing catfish farms in the Mississippi Delta now appears to exceed 25,000 birds. An average-sized farm of 127 ha (Stickley et al. 1995) would be supporting 78 herons. Similarly, these catfish farms would be supporting approximately 18,000 great egrets or 56 egrets/farm.

Despite similarities in heron and egret populations at catfish farms, the diet of these two species differed greatly in the consumption of live catfish. Live catfish made up only 8% of the great egret diet by weight, compared to 44% for herons. Catfish consumed by egrets were smaller than those consumed by herons and largely came from fingerling ponds. Based on a consumption rate of 0.3 live catfish/h, egrets would consume 4.5 fingerlings per 15-h day. This represents a potential loss of almost 92,000 fish/farm per yr (4,600 fish/pond per yr) from average egret populations frequenting the average farm. However, this may be a relatively small percentage loss from fingerling ponds where stocking rates often exceed 750,000 fish/pond. In addition, consumption of live catfish occurred primarily during the spring and fall, coinciding with the times of year that enteric septicemia of catfish (ESC), an important bacterial disease, is most prevalent (Tucker and Robinson 1990). Thus, many of the catfish consumed by egrets may have been lost anyway from disease. Hodges (1989) reported that egrets were primarily attracted to ponds where small catfish were dying and only consumed dead catfish. Although we saw a small percentage of live catfish consumed by egrets, it was not known whether these fish were in the process of dying.

Compared to egrets, great blue herons have a larger potential economic impact on catfish production. Similar to our data, Stickley et al. (1995) found that the heron diet was composed of 41% catfish by weight or 123 g of catfish/d. In contrast to Stickley et al. (1995), we observed herons consuming fewer (4 live catfish/d) but larger (34 g) catfish, but the biomass was comparable at 136 g/d. Considering average heron populations at farms and daily consumption of live catfish observed in our study, the average farm in the Delta might lose almost 114,000 (circa 3,900 kg) catfish/yr to herons. Unlike the situation with egrets, this predation is not primarily limited to fingerling ponds. Assuming a replacement cost of $0.10/fish for 16-cm fingerlings (Glahn and Brugger 1995), the annual economic impact of herons at the average catfish farm would be $11,400 or three times that reported by Stickley et al. (1995). As with egrets, the actual economic loss depends on the extent that fish consumed by herons might have been lost anyway from disease or other causes. Although additional studies are needed to document the disease incidence in catfish consumed by herons, the timing of heron predation on live catfish provides some clues to what extent this is occurring.

Stickley et al. (1995) noted that live catfish was primarily consumed in the fall when fish might be weakened from ESC. Similarly, our data suggests that spring, also an important ESC period, was when live catfish comprised the highest percentage of the herons' diet. Taylor (1992) isolated the bacteria responsible for ESC from 80% of the great blue herons collected. Considering that wading birds may well be preying on ESC infected fish, their role as vectors of this disease requires further evaluation.

This study indicates that burgeoning great blue heron populations are having an increasing impact on catfish farms in the Mississippi Delta, but that similar great egret populations have considerably less, if any, impact. Four other wading bird species were observed so infrequently at catfish ponds as not to warrant further investigation of their impact at this time. Although our estimated costs of heron predation may well justify the average wading bird control program costs of $4,000/yr reported by producers, further studies are needed to document actual production losses.

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